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Inmine Fire Tests of Mine Shaft Fire and Smoke Protection Systems

UNITED STATES DEPARTMENT OF THE INTERIOR

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Inmine Fire Tests of Mine Shaft Fire and Smoke Protection Systems

By Guy A. Johnson and David R. Forshey

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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ILLUSTRATIONS

INMINE FIRE TESTS OF MINE SHAFT FIRE AND SMOKE PROTECTION SYSTEMS

by

Guy A. Johnson[1] and David R. Forshey[2]

ABSTRACT

This Bureau of Mines report summarizes the results of efforts to develop reasonably priced, reliable mine shaft fire and smoke protection hardware for metal and nonmetal mines. The hardware was incorporated into a viable prototype system that would minimize fire and smoke hazards. The design of the system had to be sufficiently flexible to be utilized in a wide variety of metal and nonmetal mine shaft and shaft station configurations. As a result of long-term, rugged field tests, an improved (second generation) system was developed. The hardware is now commercially available.

INTRODUCTION

Electrical shorts, welding, and torch cutting account for over 50 percent of fires in noncoal underground mines since 1945. The fourth major cause of fires in mines today is spontaneous combustion. As mines become deeper and ventilation systems become more complex, the spontaneous combustion hazard will probably increase. The May 1972 fire at the Sunshine mine, Wallace, Idaho, illustrates the fire problem currently faced in deep mines. Ninety-one miners lost their lives in the disaster. Thus, miners need improved fire protection from both fast- and slow-burning fires. It would be impractical to develop a fire protection system for each part of an underground mine; the Bureau chose to initiate its underground mine fire protection hardware program at the shaft-shaft station area. A research and development contract was awarded in 1974 to the FMC Corp., Santa Clara, Calif., to develop and conduct an inmine test of a mine-shaft fire and smoke protection system. The system was successfully tested at the Hecla Mining Co.'s Silver Summit shaft near Wallace, Idaho, in 1975. In 1976 an improved, second-generation system was developed and subjected to long-term, rugged testing in Union Carbide's Pine Creek mine near Bishop, Calif. This report summarizes the results of this contract effort and other related Bureau work.

[1]Mining engineer, Twin Cities Mining Research Center, Bureau of Mines, Twin Cities, Minn.
[2]Chief, Division of Mining Research--Health and Safety, Bureau of Mines, Washington, D.C.

DESIGN CONCEPT DEVELOPMENT

Because many more miners die from smoke inhalation than from burns in underground metal and nonmetal fires, smoke protection is an important requirement of any underground fire protection system. Thus, smoke control, along with prompt, reliable fire sensing and suppression, was a prime concern in designing the system.

Major factors considered in the development of this system follow:

1. Fire--Class, size, speed of propagation, components.

2. Control system--Manual-semiautomatic-automatic, visual-audible warning, logic.

3. Sensor--Optical, thermal, gas-smoke, pressure.

4. Extinguishing agent--Dry powder, foam, gas, water.

5. Cost--Development, production.

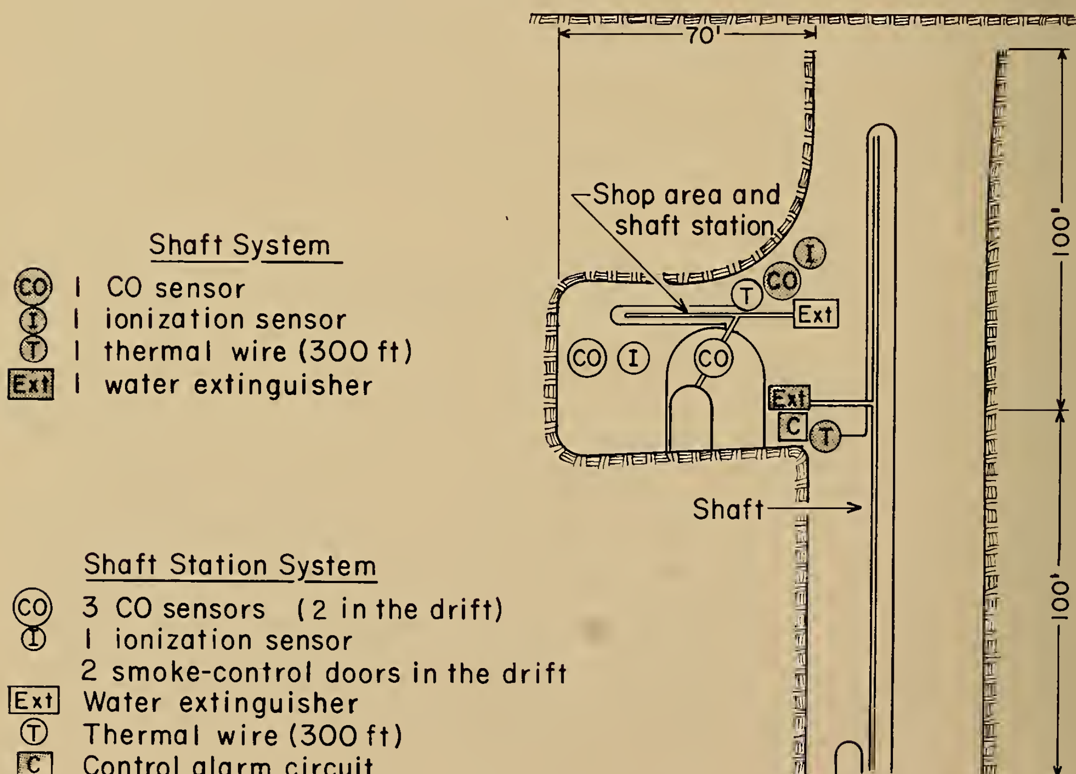
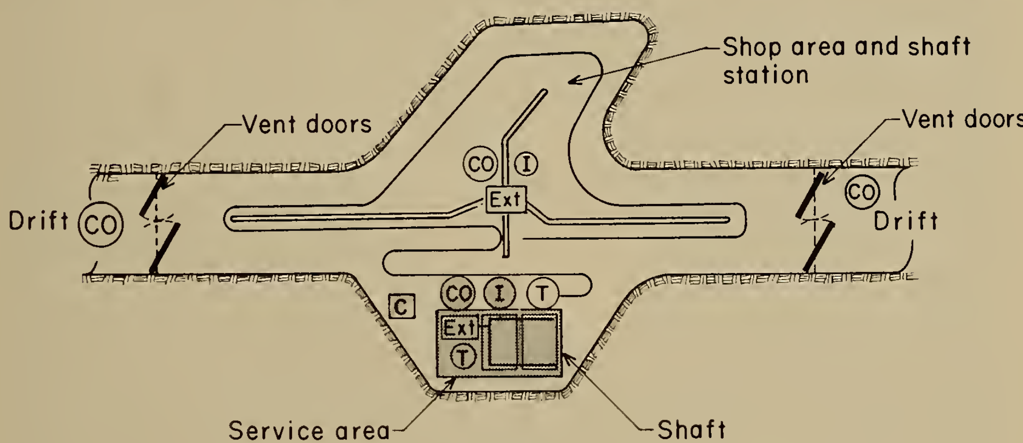


FIGURE 1. - Mine shaft fire protection system design concept—elevation view.

Reliable fire sensing is the integral function of any underground fire protection system. Figures 1 and 2 depict the concept. Since heat, gas, and smoke contribute to the underground hazard and sensing devices vary in reliability in the rugged mine environment, three types are used by the system: thermal wire (heat) sensors, carbon monoxide sensors, and ionized particle (smoke) sensors. The heat sensor uses an inexpensive thermometric core wire, and is strung in the shaft-shaft station area. This sensor is only reliable for detecting large or close fires. The CO sensor uses an inexpensive electrochemical sensing element, but is of low reliability in a mine because it cannot be calibrated. The smoke sensor is an ionized chamber combustion particle-type detector, which was developed and built by Anglo-American in South Africa for their deep gold mines. It is of reasonable cost and proved to be the most rugged and reliable underground fire sensor tested, especially in high-ventilation areas.

The underground fire protection system is also composed of remote-control smoke-control doors and sprinklers; there are two separate routings underground composed of a single pair of twisted wires connected to the system's surface control unit. The underground control units of the system are set up at each shaft-shaft station area. The Bureau of Mines is currently developing and inmine testing improved, domestically produced, reliable underground fire sensors for use with the shaft fire system or as a "fire warning only" system.



KEY

Shaft Station System

- (CO) 3 CO sensors
- (I) 1 ionization sensors
- 2 vent doors
- [Ext] Water-and-foam extinguisher
- (T) Thermal wire (300 ft)
- [C] Control alarm circuit

Shaft System

- (CO) 1 CO sensor
- (I) 1 ionization sensor
- (T) 1 thermal wire (300 ft)
- [Ext] 1 water-and-foam extinguisher

FIGURE 2. - Mine shaft fire protection system design concept—plan view.

When there is a fire, the underground fire protection system uses the fire detectors to alert the miners and, in turn, the remote-control smoke-control doors and sprinklers are turned on to protect the miners from smoke inhalation and to suppress the fire. Then, the surface control unit receives multiplex fire-warning signals from underground through the two separate routings composed of a single pair of twisted wires. The system can also be activated from the surface to warn the underground miners (via horns and lights) of a fire situation, and a stench-warning system would be activated to alert the miners of a fire. The underground sprinklers and smoke-control doors can be opened or closed from either a local control unit or the surface control unit. Although automatic sprinkler actuation is not a feature of the system, such a design alternative could be easily added.

INMINE FIRE TESTING OF THE FIRST-GENERATION SYSTEM

In order to check out the components of the system before it was installed underground, in March 1975, a shaft-shaft station mockup (fig. 3) was constructed at the FMC plant, and the prototype hardware of the system was evaluated in a simulated mine environment. Mockup testing was highlighted in March 1975 when the capabilities of the system were demonstrated to the Bureau, the Mining Enforcement and Safety Administration (MESA),[3] and industry representatives using fires set in the simulated shaft-shaft station. The 4- by 4- by 2-foot steel box used to contain the fire in the mockup testing was also used in the inmine fire testing. (See figure 4.) Following component testing, a final design for a first-generation mine shaft fire and smoke protection system was developed. Figure 5 depicts the modular electronics used in the surface control unit. Figure 6 shows the first-generation underground control unit. Figure 7 depicts the double-acting, remote-control smoke-control door (with a man entering through the emergency manway as installed in the mine). Figure 8 shows one of the two remote-control solenoid-operated valves used to actuate the dry-pipe sprinklers in the shaft-shaft station area. Figure 9 is a schematic of the complete first-generation mine shaft fire and smoke protection system.

In April 1975, a prototype system based on the idealized design was installed in the 3,000-level shaft station of the Silver Summit shaft, which is the center of the Coeur d'Alene mining district, near Wallace, Idaho. The shaft is part of Hecla Mining Co.'s Consolidated Silver holdings and is a part of the exhaust ventilation network for the Sunshine mine. The hardware was then successfully demonstrated to the Bureau of Mines, MESA, and Hecla personnel by an inmine fire test. Figures 10 through 14 show the lighting, burning, and successful extinguishment of the underground fire test. This was one of the first inmine fire demonstrations ever performed and required considerable cooperation between the mine and MESA for the proper variances, planning, and inmine work.

[3] MESA became the Mine Safety and Health Administration (MSHA), U.S. Department of Labor, on March 9, 1978.

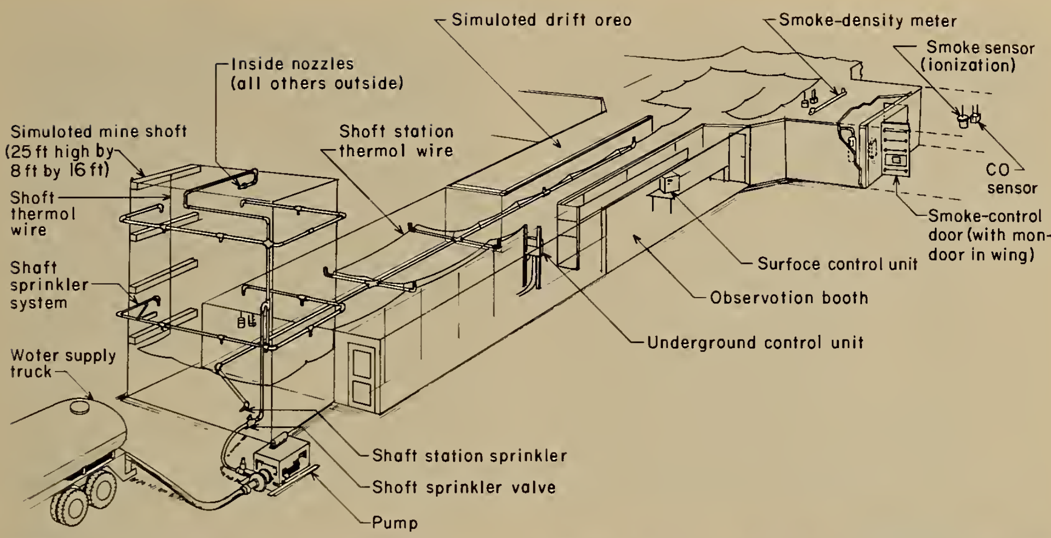


FIGURE 3. - FMC/USBM factory demonstration test area.

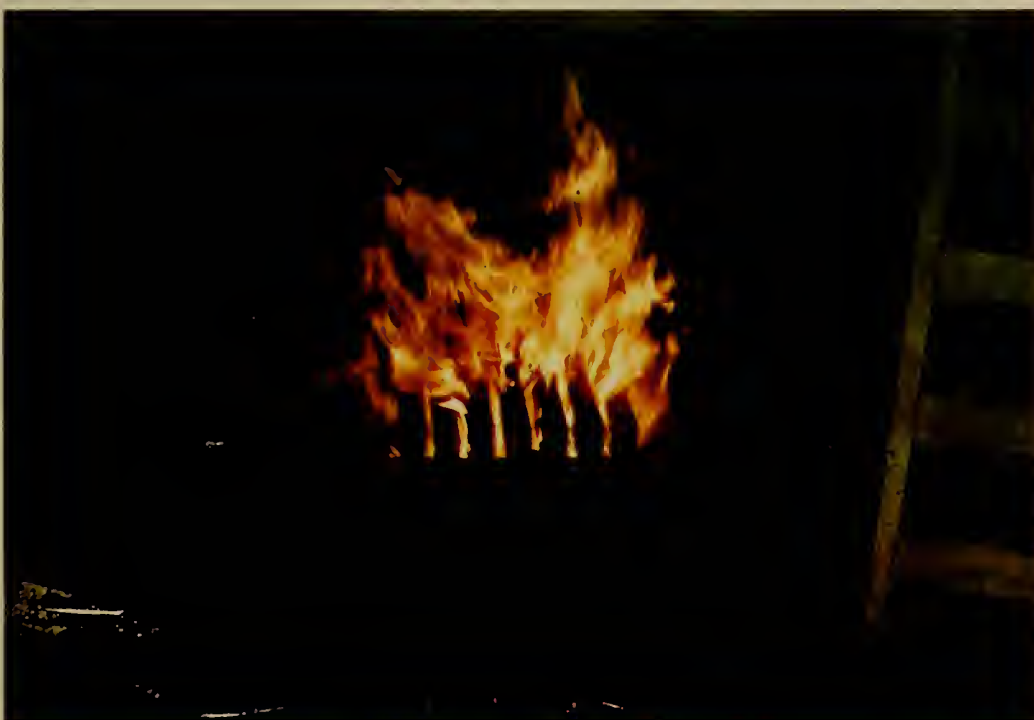


FIGURE 4. - Fire box used in the mockup testing and in the preceding inmine fire testing of both prototype systems.

FIGURE 5. - Ruggedized electronics used in the surface control unit of the first-generation system.

FIGURE 6. - Underground control unit from the first mine shaft fire and smoke protection system.

FIGURE 7. - Smoke-control door used in both systems.

A report summarizing this work on the development of the first-generation system and inmine testing is currently available.[4]

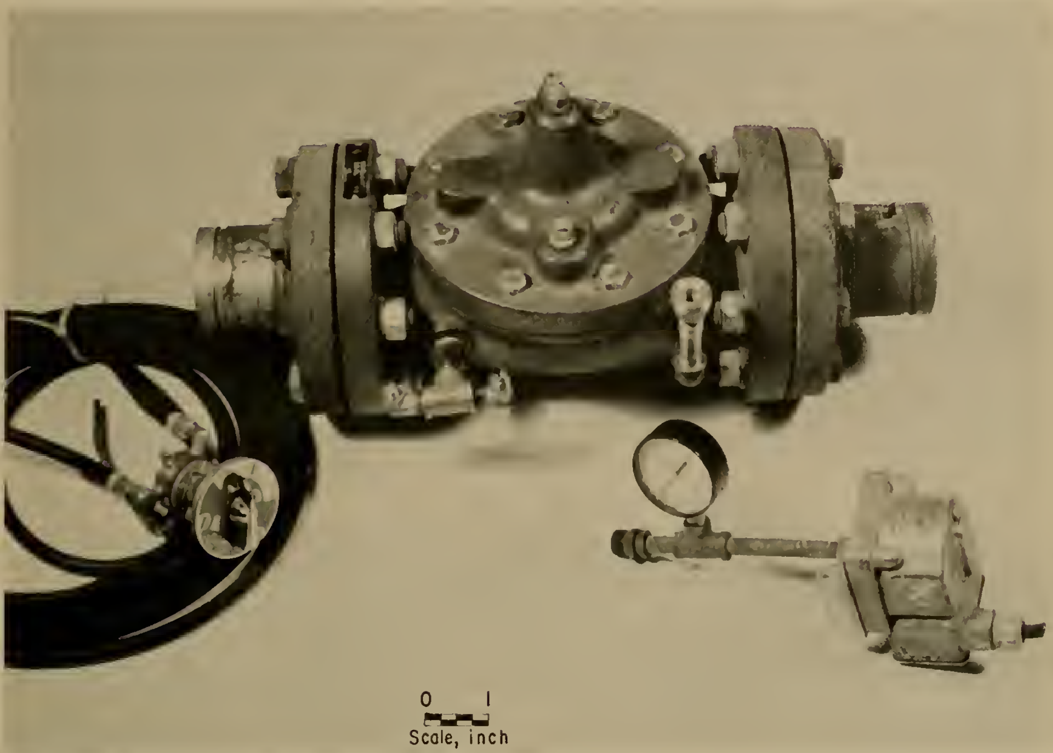


FIGURE 8. - Remote-control sprinkler valve used in both systems.

[4] FMC Corp. Mine Shaft Fire and Smoke Protection System (Final Report). Volume I. Design and Demonstration. BuMines Open File Rept. 24-77, July 1975, 407 pp.; available for reference at Bureau of Mines facilities in Denver, Colo., Twin Cities, Minn., Bruceton and Pittsburgh, Pa., Spokane, Wash.; Department of Energy, Morgantown Energy Research Center, Morgantown, W. Va.; the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va., PB 263 577/AS. Also available in the form of a technology transfer film from the Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213.

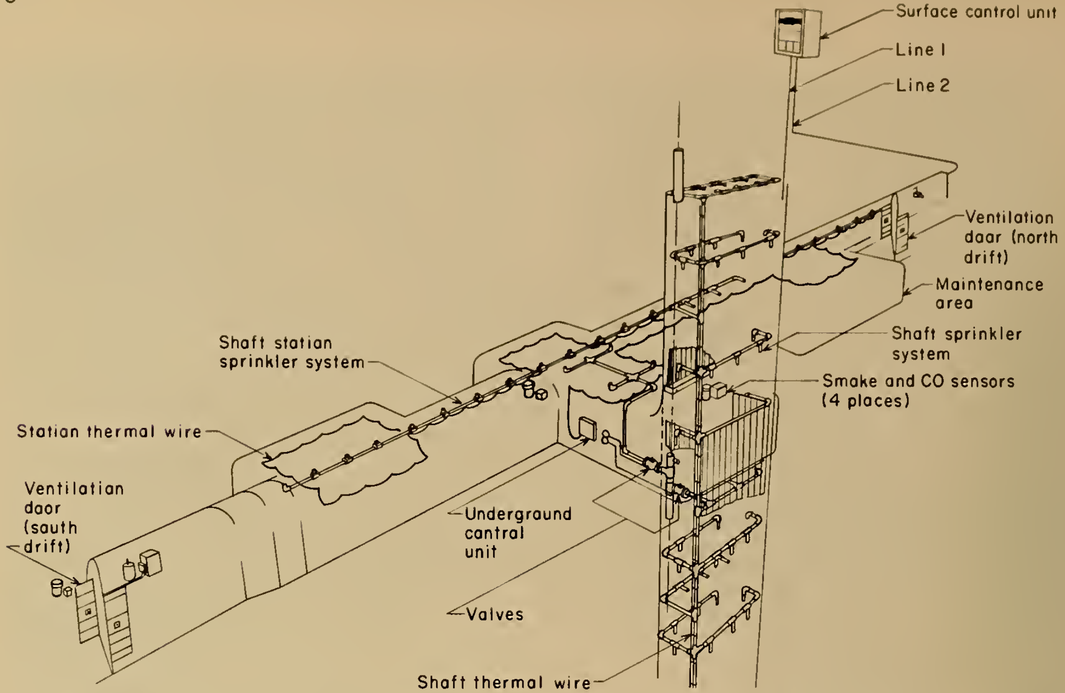


FIGURE 9. - Schematic of the total first-generation mine shaft fire and smoke protection system.

FIGURE 10. - Lighting the underground fire test in the Silver Summit shaft.

FIGURE 11. - Fire starting to burn in the test fire box.

FIGURE 12. - Fire burning in the Silver Summit shaft mine.

FIGURE 13. - Test fire being extinguished via remote control from the surface control unit.

FIGURE 14. - Fire completely out after the test burn in the Silver Summit shaft mine.

INMINE FIRE TESTING OF THE SECOND-GENERATION SYSTEM

After the Coeur d'Alene fire tests, an improved (more cost-effective) mine shaft fire and smoke protection system design was developed. This second-generation system was then installed for long-term reliability testing in Union Carbide's Pine Creek mine, Bishop, Calif. This effort helped evaluate the ruggedness of the system and demonstrated how it can be modified for typical underground fire protection situations.

Figure 15 shows the locations of the multiple-level installation of the second-generation prototype at the Pine Creek mine. Figure 16 depicts the surface control unit of the second-generation system. (Note the two-level control display.) Figure 17 depicts the second-generation design of the underground control unit (at Pine Creek). This, along with all controls, is "modularized" for easy repair.

Figure 18 is a sketch of the area where the inmine fire tests for the second prototype system took place July 1976. Figure 19 shows the successful sensing and extinguishment of the "C" level test fire at Pine Creek. Figures 20, 21, and 22 depict the fire test at the 1,500 level.

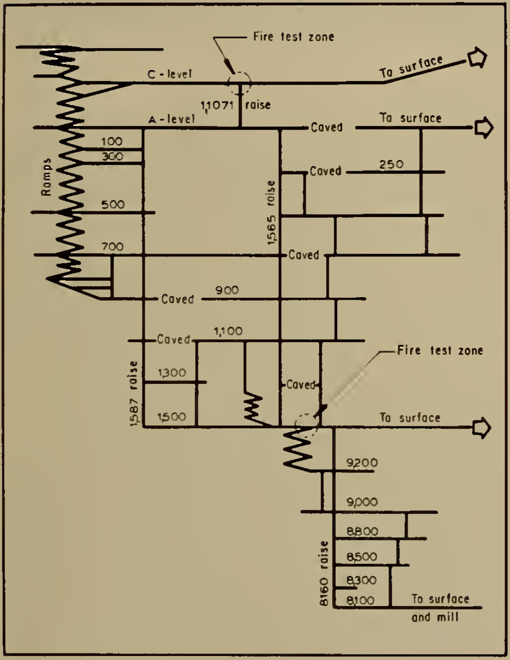


FIGURE 15. - Locations of the underground fire tests of the second-generation system.

FIGURE 16. - Surface control unit of the second prototype system.

FIGURE 17. - Second-generation underground control unit.

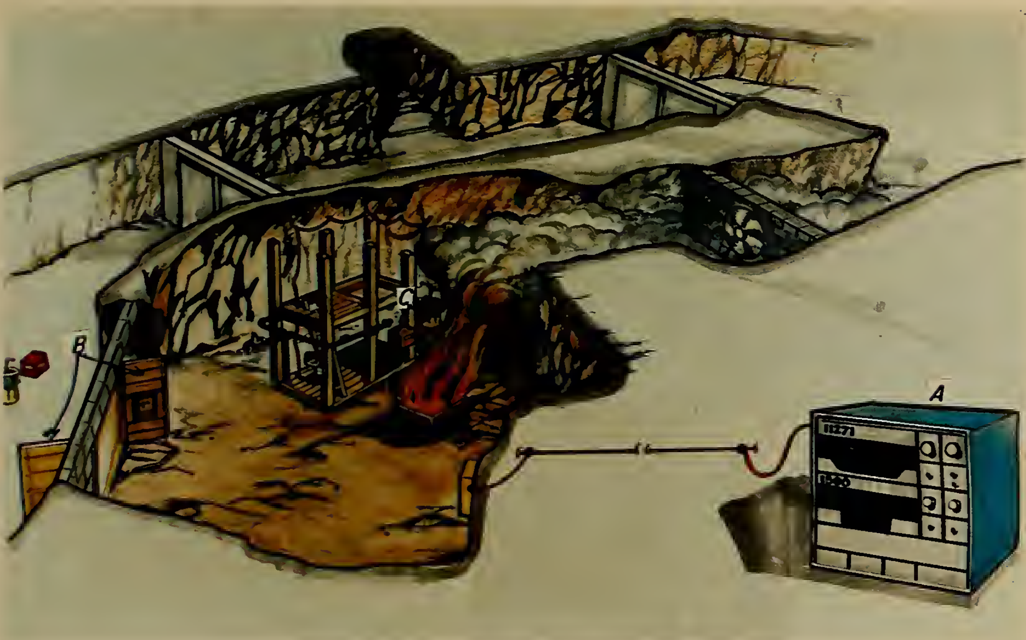


FIGURE 18. - Schematic of one of the two underground fire tests of the second mine shaft fire and smoke protection systems. The master control unit *(A)* is located at the surface of the mine. Smoke-control doors *(B)* and the fire sensors *(C)* are located at the top of the shaft.

FIGURE 19. - "C" level Pine Creek test fire completely extinguished by the second-generation system.

FIGURE 20. - Level 1,500 Pine Creek test fire starting to burn.

FIGURE 21. - Level 1,500 Pine Creek test fire burning.

FIGURE 22. - Level 1,500 Pine Creek test fire extinguished via remote control from the surface control unit.

This followup work produced three system application reports that describe how the technology of the shaft fire system can be used to improve fire protection in maintenance areas, underground storage areas, and underground fuel storage and transfer areas.[5]

COST-EFFECTIVENESS OF THE SYSTEMS

Both mine shaft fire and smoke protection system designs have fast response to underground mine fire situations in or near a shaft-shaft station area. The remote-control sprinklers are more effective in extinguishing shaft fires than the commonly used shaft-collar water rings, because water from a water ring only drops down the center of the shaft (where there is little burnable material), but the shaft-shaft station sprinklers wet both sides of the shaft lagging, and the back and walls of the shaft station.

The cost of either system is estimated to be from $10,000 to $40,000 per shaft station level protected, depending on the sophistication of the hardware installed, plus $50,000 for the surface control unit. A mine shaft fire and smoke protection system is a significant investment. This technology represents a significant contribution to cost-effective fire safety in underground mines when the price of the system is compared with the rehabilitation cost of a damaged shaft and the associated loss of production.

SUMMARY

The Bureau of Mines, using contract research, defined the noncoal mine shaft fire and smoke protection hazard, then designed, fabricated, and inmine tested prototype hardware that protects miners and mine property more efficiently and cost-effectively than the shaft-collar water rings now commonly used. Both first- and second-generation mine shaft fire and smoke protection system designs use thermal, carbon monoxide, and smoke detectors, plus

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[5] FMC Corp. System Application Report. Mine Shaft Fire and Smoke Protection System. Interim Report. Volume I. Mine Fire Protection for Underground Maintenance Shops. BuMines Open File Rept. 43-77, 1976, 17 pp.; available from National Technical Information Service, Springfield, Va., PB 265 070/AS.

______. System Application Report. Mine Shaft Fire and Smoke Protection System. Interim Report. Volume II. Mine Fire Protection for Underground Storage Areas. BuMines Open File Rept. 43-77, 1976, 17 pp.; available from National Technical Information Service, Springfield, Va., PB 265 071/AS.

______. System Application Report. Mine Shaft Fire and Smoke Protection System. Interim Report. Volume III. Mine Fire Protection for Underground Fuel Storage and Transfer Area. BuMines Open File Rept. 43-77, 1976, 17 pp.; available from National Technical Information Service, Springfield, Va., PB 265 072/AS.

All three reports are available for consultation at Bureau of Mines facilities in Denver, Colo., Twin Cities, Minn., Bruceton and Pittsburgh, Pa., Spokane, Wash.; at the Department of Energy libraries in Morgantown, W. Va., and Carbondale, Ill.; and at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.

remote-control smoke-control doors and sprinklers at the shaft-shaft station area. The first-generation system was successfully demonstrated by an inmine fire test in the Silver Summit shaft near Wallace, Idaho, in the spring of 1975. Long-term testing of a second-generation design then was conducted to demonstrate the economy and reliability of the hardware. The second test started in September 1975 in the Union Carbide Pine Creek mine, Bishop, Calif., and ended in July 1976, with the successful inmine fire testing of the modified system in two levels of the mine.

Current work by the Bureau involves the long-term, inmine testing of improved mine fire-sensing hardware. One such test was demonstrated at Hecla's Lakeshore mine, Casa Grande, Ariz. (See figure 23.) Other related work involves cost-sharing installations of shaft fire systems in different parts of the country so that industry professionals can get a first-hand look at production-run hardware. Both FMC and Collins Radio of Cedar Rapids, Iowa, are cooperating with the Bureau to make this technology available to the mining industry.

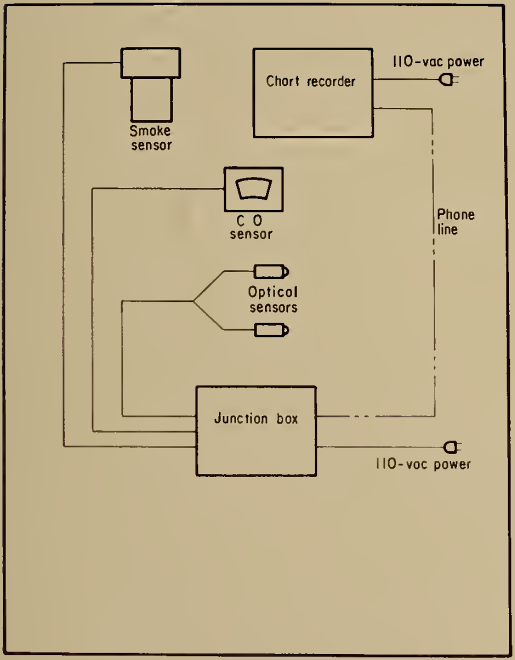

FIGURE 23. - Typical prototype underground fire sensor package undergoing long-term, inmine reliability testing.

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